ILLINOIS NATURAL HISTORY SURVEY

FINAL PROGRESS REPORT

Section of Wildlife Research

Population Ecology of the Woodcock in East-central Illinois

Project No.: U.S. INTER 14-16-0009-81-009

By

WILLIAM R. EDWARDS

15 September 1983

FINAL PROGRESS REPORT[a]

Period Ending: 30 September 1983

Project No.: U.S. INTER 14-16-0009-81-009

I Title: Population Ecology of the Woodcock in East-central Illinois.

II Principal Investigator: Dr. William R. Edwards, Ill. Nat. Hist. Survey, Champaign 61820.

III Cooperating Agencies: Illinois Natural History Survey, U.S. Fish & Wildlife Service, University of Illinois, and Illinois Department of Conservation.

IV Objective: To collect such additional data as are necessary to prepare a bulletin to be published on the biology and ecology of the woodcock in east-central Illinois. This publication would stress abundance population dynamics, habitat relations, movements and migration.

V Initiation: This study was initiated 1 October 1980. Support for the project assistant, Mr. Richard Siemers, was provided by a grant from the U.S. Fish and Wildlife Service under the Accelerated Research Program (ARP) of that agency. Additional support for travel and for the principal investigator was supported by the Illinois Natural History Survey; the grant is administered by the

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[a]Note: Funding for this study ended effective 30 September 1982 due to lack of funds available to the U.S. Fish & Wildlife Service to sustain research approved and scheduled for conduct and completion under ARP.

University of Illinois. Several aspects of the current project continue elements of field research on woodcock ecology initiated in 1977 under U.S. Interior 14-16-0009-78-005 (Analysis of feather prints of Illinois populations of woodcock and doves).

VI Summary of Progress:

Banding: Banding of woodcock was done during the period 23 March through 9 June, 1982. A summary of this banding is attached as is a summary of recapture of banded woodcock. A total of 159 woodcock were banded through 9 June 1982 on this project. Banding was terminated 1 July 1982 because of loss of funding effective 1 October 1982.

Census: For 5 consecutive years (1978-82) peenting grounds were censused on the Forest Glen Area, Vermilion County. Locations of regularly used peenting grounds were plotted on reference maps and aerial photos. Locations of peenting grounds were also determined for portions of the Kennekuk Cove Area, Vermilion County and for the Salt Fork Forest Preserve, Champaign County. Analyses of spatial relationships among peenting grounds with respect to habitat, area, and year were initiated; a ms is now in preparation. Concepts of critical individual distance requirements as well as concepts of habitat structural requirements are essential to efficient management to preserve and perpetuate species such as woodcock in successional environments. The concept of critical distance is inadequately appreciated in management of wildlife habitat.

Reports: Progress reports covering the period ending 31 December 1981 was completed and submitted in February 1982 and a report covering the period ending 30 June 1982 was completed 30 September 1982. This present report constituted the final progress report for the project.

Manuscripts: The following manuscripts were completed:

a. Exploratory experiments on the stability of mineral profiles of feathers; Wm. R. Edwards and Kenneth E. Smith. This effort represents a completion of work initiated under the previously funded A.R.P. study relating to woodcock in Illinois. Work relates to technique development for analysis of feather mineral profiles as a basis for differentiation of local and migratory cohorts of woodcock in Illinois; a copy of the complete ms is appended. It has been accepted for publication in The Journal of Wildlife Management.

b. Organochlorine insecticide residues and PCB's in tissues of woodcock from east-central Illinois, 1978-1979; Wm. R. Edwards, Richard Siemers, and Ronald E. Duzan. Specimens collected for other purposes were subjected to pesticide analysis. Analyses indicated environmental contamination by pesticides to be widespread but at relatively low and decreasing levels. Data obtained provide a baseline for future analyses. Pesticide profiles appear to have possible utility when used in conjuntion with feather mineral profiles in differentiation of local and migratory cohorts of woodcock in Illinois; a copy of the final draft is appended. This ms is currently in press in Environmental Contamination and Toxicology.

<u>Analyses in Progress</u>: The following analyses are currently in various stages of completion:

a. Spatial relationships--discussed above.

b. Census data--almost complete. Work will lead to a ms on density, space, year-to-year, and within year patterns of woodcock abundance in east-central Illinois.

c. Evaluation of earthworms as a nutrient resource for woodcock; analyses including proximate analysis, amino acid profiles, mineral profiles, and energy (R.E. Siemers).

d. Relative abundance of earthworms in primary cover used by woodcock in east-central Illinois (R.E. Siemers).

e. Identification of common species of earthworms in nocturnal and diurnal woodcock habitats in east-central Illinois (R.E. Siemers).

f. Quantitative characterization of structural configurations of primary habitats used by resident woodcock in east-central Illinois.

g. The effects of season, weather, and lunar cycle on the duration of evening activity of peenting woodcock (R.E. Siemers).

h. Analysis of feather mineral profiles of woodcock, mourning doves and robins from east-central Illinois. Analysis of feathers complete but yet to be verified.

i. Preparation of a Natural History Survey Bulletin on the woodcock in east-central Illinois. Tentatively outlined.

Prepared by: William R Edwards

William R. Edwards
Professional Scientist
Section of Wildlife Research
Illinois Natural History Survey

Date: 15 September 1983

Approved by: Glen Sanderson

Glen C. Sanderson, Head
Section of Wildlife Research
Illinois Natural History Survey

Date: 16 September 1983

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
4	6/30/83	MON-RA-83-242 (lcb)	

5. ISSUED BY CODE

Department of the Interior
U.S. Fish and Wildlife Service
Div. of Contracting and General Services
Washington, D.C. 20240

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR CODE FACILITY CODE
NAME AND ADDRESS
(Street, city, county, state and ZIP Code)

The Board of Trustees of the
University of Illinois
Contracts and Grants
105 Davenport House
809 South Wright Street
Champaign, Illinois 61820

8.
☐ AMENDMENT OF SOLICITATION NO. ________
DATED ________ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. 14-16-0009-81-009
DATED 1/29/81 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

Previous Contract Amount	$29,800.00
Amount Reduced by this Modification	10,900.00
New Contract Amount	$18,900.00

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ________
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Termination for convenience of the Government - Clause 13 of the General Provisions
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

Contract No. 14-16-0009-81-009 is hereby modified as follows:

1. As a result of the unavailability of Fiscal Year 1983 funding for the Accelerated Research Program, the total estimated amount of the Contract is hereby reduced from $29,800.00 by $10,900.00 to $18,900.00 which is the amount of funding obligated to the Contract..

2. It is recognized that without the full level of funding, the Contractor cannot complete the total work requirements of the Contract. This Contract shall be considered complete upon submission of a final voucher and the following items of deliverables to the FWS Project Officer:

Modification continues

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN original & 2 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR The Board of Trustees of the University of Illinois
BY Craig S. Bazzani
(Signature of person authorized to sign)
Craig S. Bazzani, Comptroller

17. UNITED STATES OF AMERICA
BY Linda C. Boor
(Signature of Contracting Officer)
FWS 4-81-5

15. NAME AND TITLE OF SIGNER (Type or print)
ATTEST: Earl W. Porter
Earl W. Porter, Secretary

16. DATE SIGNED 7/20/83

18. NAME OF CONTRACTING OFFICER (Type or print)
Linda C. Boor

19. DATE SIGNED 7/20/83

a. A brief progress report which summarizes the major results and findings of the two-year research efort actually performed.

b. A copy of each of the following manuscripts:

   1) "Explanatory Experiments on the Stability of Numerial Profiles of Feathers." Dr. William Edwards, Kenneth Smith.

   2) "Organochlorine Insecticide Residues and PCBS in Tissues of Woodcock from East Central Illinois" Dr. William Edwards, Richard Simmers and Ronald Duzen.

These deliverables shall be provided as soon as is practicable but no later than September 30, 1983.

End of Modification No. 4

Organochlorine Insecticide Residues and PCB's in Tissues of Woodcock, Mourning Doves, and Robins From East-Central Illinois, 1978-1979

William R. Edwards, Ronald E. Duzan, and Richard J. Siemers

Section of Wildlife Research,

Illinois Natural History Survey, Champaign, IL 61820

Use of DDT in agriculture was widespread through the late 1940's, reached a peak in the mid-1950's, and declined rapidly thereafter. In the mid-1960's, aldrin was used on about half the acreage planted to corn in Illinois, but its use declined after 1966 and had effectively ceased after 1976 (D. KUHLMAN, Illinois Natural History Survey [INHS], unpublished data; and STEVENSON MOORE III, INHS, personal communication). Use of heptachlor in Illinois effectively ended in 1978. Dieldrin was apparently never used extensively and its limited use ended about 1964. Nevertheless, these chlorinated hydrocarbon and cyclodiene pesticides persist in soils (NASH and WOOLSON 1967, PIMENTEL 1971) and apparently are conserved by adsorption in the upper soil layers where they are associated with organic matter (EDWARDS 1970, MEHNER & WALLACE 1959).

Polychlorinated biphenyl compounds (PCB's) were introduced in 1929 and today are ubiquitous in the environment (DUSTMAN et al. 1971). Levels of PCB's in animals relate to food habits and may be magnified hundreds of times through food chains from prey to predator (PRICE 1977, RISEBROUGH et al. 1968). HEATH et al. (1970) concluded that the effects of PCB's and DDE are additive, not synergistic. DUSTMAN et al. (1972) reported that PCB residues above 10 ppm in eggs are cause for concern.

PRICE (1977) concluded that, although still widespread in Canadian wildlife, the incidence of DDE has apparently dropped since the use of DDT ended there in 1968-1969. The breeding population of robins on the campus of Iowa State University, Ames, was more abundant when censused by WILLSON (1978) in 1977 than when censused by WELLER (1971) in 1962-1970 at the height of a local Dutch-elm-disease eradication program utilizing DDT.

Reported here are levels in ppm of heptachlor, heptachlor epoxide, dieldrin, p,p'-DDE (DDE), and PCB residues assayed in muscle, heart, liver, brain, and fatty tissues of woodcock (*Philohela minor*), mourning doves (*Zenaidura macroura*), and robins (*Turdus migratorius*) from east-central Illinois in 1978 and 1979.

MATERIALS AND METHODS

The sample specimens (available from another study) were taken from study areas near Westville in Vermilion County and near

Shelbyville in Shelby County, in August 1978 and 1979. Samples included 9 woodcock, 5 doves, and 6 robins from Vermilion County and 5, 3, and 0, respectively, from Shelby County; the location for 1 woodcock is not known. Wet tissue samples were homogenized, saponified, and then extracted with 50 ml of nanograde hexane. The hexane extract was washed three times with ultrapure water, poured through a funnel of anhydrous Na_2SO_4 to remove residual water, and then placed on a steam bath and reduced to a volume of 2-5 ml under a 3-ball Snyder column. Each sample was fractionated on a 30-gm florisil column. The first fraction was eluted with 90 ml of hexane to recover the PCB's; the second fraction, eluted with 10 percent ethyl ether/hexane, contained the remaining chlorinated hydrocarbons. The samples were then reduced to a volume suitable for gas chromatographic analysis. The analyses were performed using a Varian-Aerograph Series 2100 gas chromatograph with a 63Ni electron capture detector operated at 250°C. The analytical column was a 6' x 1/4" O.D. x 2 mm I.D. glass column packed with 2.5% OV-210 and 1.0% OV-17 coated on a 100-120 mesh Supelcoport. The column temperature was maintained at 190°C and the injection port at 210°; the electrometer was operated at 4×10^{-10} amperes. The carrier gas was O_2-free nitrogen at a flow rate of 40 ml/min. Detection limits were calculated to be 0.0001 ppm. Because of limited sample sizes and generally low levels of pesticides, tests of statistical differences were not attempted.

RESULTS AND DISCUSSION

All 15 woodcock sampled contained insecticides; however, none contained either heptachlor or aldrin (Table 1). Of the 15, heptachlor epoxide was found in 12, dieldrin in all 15, DDE in 4, and PCB's in 4. Highest levels of the respective compounds in woodcock tissues were 0.2532 ppm heptachlor epoxide in fat, 21.2103 ppm dieldrin in fat (the magnitude and inconsistency of this value suggest possible contamination), 0.7661 ppm DDE in liver, and 12.4878 ppm PCB's in fat.

All 8 mourning doves contained insecticides (Table 2). As with the woodcock, none of the doves contained either heptachlor or aldrin. Of the 8 doves, all showed heptachlor epoxide and measurable dieldrin; DDE was found in 3 and PCB's in 1. Highest levels detected in the doves were 0.1319 ppm heptachlor epoxide in fat, 0.1785 ppm dieldrin in brain, 4.7526 ppm DDE in fat, and 0.3718 ppm PCB's in fat.

All 6 robins contained insecticides (Table 3). Of the 6 robins, heptachlor was found in 2, heptachlor epoxide in 4, aldrin in 1, dieldrin in 5, and PCB's in 2. Highest levels in robins were 0.3354 ppm heptachlor in brain, 0.9677 ppm heptachlor epoxide in brain, 0.0052 ppm aldrin in brain, 0.0162 ppm dieldrin in muscle, 0.3158 ppm DDE in heart, and 6.7438 ppm PCB's in fat.

In general, levels of organochlorine insecticides were less than 1 ppm. In only one tissue did PCB's exceed 10 ppm. Levels of heptachlor epoxide were higher in robins than in mourning doves

Table 1. Incidence of insecticides and PCB's in ppm[1] in tissues of woodcock from east-central Illinois, August 1978 and 1979.

Tissue	Heptachlor	Heptachlor Epoxide	Aldrin	Dieldrin	p,p'-DDE	PCB's
Muscle						
Rate	0/15	5/15	0/15	13/15	3/15	2/15
Mean	<0.0001	0.0086	<0.0001	0.0343	0.0074	0.299
Range	<0.0001	<0.0001-0.0337	<0.0001	<0.0001-0.297	<0.0001-0.0620	<0.0001-4.48
Liver						
Rate	0/11	3/11	0/11	8/11	2/11	1/11
Mean	<0.0001	0.0071	<0.0001	0.0450	0.0806	0.0225
Range	<0.0001	<0.0001-0.0539	<0.0001	<0.0001-0.209	<0.0001-0.766	<0.0001-0.247
Heart						
Rate	0/15	8/15	0/15	14/15	3/15	1/15
Mean	<0.0001	0.0120	<0.0001	0.0567	0.0173	0.0053
Range	<0.0001	<0.0001-0.0895	<0.0001	<0.0001-0.455	<0.0001-0.126	<0.0001-0.0791
Brain						
Rate	0/15	4/15	0/15	12/15	1/15	0/15
Mean	<0.0001	0.0094	<0.0001	0.0206	0.0039	<0.0001
Range	<0.0001	<0.0001-0.0948	<0.0001	<0.0001-0.234	<0.0001-0.0580	<0.0001
Fat						
Rate	0/6	4/6	0/6	6/6	0/6	1/6
Mean	<0.0001	0.0634	<0.0001	3.7174[2] (0.2187)	<0.0001	2.08
Range	<0.0001	<0.0001-0.253	<0.0001	<0.0001-21.2[2]	<0.0001	<0.0001-12.5
Sum						
Rate	0/62	24/62	0/62	53/62	9/62	5/62
%	0	39	0	85	15	8

[1]Means computed using an assumed level of 0.00005 for values less than 0.0001.

[2]Possibly contaminated sample.

Table 2. Incidence of insecticides and PCB's in ppm[1] in tissues of mourning doves from east-central Illinois, August 1978 and 1979.

Tissue	Heptachlor	Heptachlor Epoxide	Aldrin	Dieldrin	p,p'-DDE	PCB's
Muscle						
Rate	0/8	5/8	0/8	6/8	2/8	0/8
Mean	<0.0001	0.0203	<0.0001	0.0103	0.0138	<0.0001
Range	<0.0001	<0.0001-0.121	<0.0001	<0.0001-0.0260	<0.0001-0.1061	<0.0001
Liver						
Rate	0/7	5/7	0/7	6/7	1/7	0/7
Mean	<0.0001	0.0079	<0.0001	0.0107	0.0031	<0.0001
Range	<0.0001	<0.0001-0.0245	<0.0001	<0.0001-0.0317	<0.0001-0.0211	<0.0001
Heart						
Rate	0/6	2/6	0/6	5/6	1/6	0/6
Mean	<0.0001	0.0032	<0.0001	0.0198	0.0179	<0.0001
Range	<0.0001	<0.0001-0.0174	<0.0001	<0.0001-0.0878	<0.0001-0.107	<0.0001
Brain						
Rate	0/4	2/4	0/4	3/4	0/4	0/4
Mean	<0.0001	0.0247	<0.0001	0.0503	<0.0001	<0.0001
Range	<0.0001	<0.0001-0.0816	<0.0001	<0.0001-0.179	<0.0001	<0.0001
Fat						
Rate	0/4	2/4	0/4	4/4	3/4	1/4
Mean	<0.0001	0.0497	<0.0001	0.0555	1.2676	0.0930
Range	<0.0001	<0.0001-0.132	<0.0001	<0.0230-0.122	<0.0001-4.75	<0.0001-0.372
Sum						
Rate	0/29	16/29	0/29	24/29	7/29	1/29
%	0	55	0	83	24	3

[1]Means computed using an assumed level of 0.00005 for values less than 0.0001.

Table 3. Incidence of insecticides and PCB's in ppm[1] in tissues of robins from east-central Illinois, August 1978 and 1979.

Tissue	Heptachlor	Heptachlor Epoxide	Aldrin	Dieldrin	p,p'-DDE	PCB's
Muscle						
Rate	1/6	4/6	0/6	3/6	1/6	0/6
Mean	0.0089	0.0303	<0.0001	0.0032	0.0017	<0.0001
Range	<0.0001-0.0533	<0.0001-0.0881	<0.0001	<0.0001-0.0162	<0.0001-0.0102	<0.0001
Liver						
Rate	0/5	4/5	0/5	3/5	1/5	0/5
Mean	<0.0001	0.0107	<0.0001	0.0026	0.0046	<0.0001
Range	<0.0001	<0.0001-0.0167	<0.0001	<0.0001-0.0098	<0.0001-0.0230	<0.0001
Heart						
Rate	0/4	3/4	0/4	1/4	3/4	1/4
Mean	<0.0001	0.0632	<0.0001	0.0017	0.0833	0.288
Range	<0.0001	<0.0001-0.118	<0.0001	<0.0001-0.0066	<0.0001-0.316	<0.0001-1.15
Brain						
Rate	2/6	3/6	1/6	2/6	1/6	2/6
Mean	0.0576	0.283	0.0009	0.0013	0.0043	1.48
Range	<0.0001-0.335	<0.0001-0.968	<0.0001-0.0052	<0.0001-0.0061	<0.0001-0.0258	<0.0001-6.74
Sum						
Rate	3/21	14/21	1/21	9/21	6/21	3/21
%	14	67	5	43	29	14

[1]Means computed using assumed value of 0.00005 for values less than 0.0001.

Table 4. Mean levels of heptachlor epoxide and dieldrin in tissues of woodcock, mourning doves, and robins from east-central Illinois, August 1978 and 1979.

	Heptachlor Epoxide			Dieldrin		
Tissue	Woodcock	Mourning Dove	Robin	Woodcock	Mourning Dove	Robin
Muscle	0.0086	0.0203	0.0303	0.0343	0.0103	0.0032
Liver	0.0071	0.0079	0.0107	0.0450	0.0107	0.0026
Heart	0.0120	0.0032	0.0632	0.0567	0.0198	0.0017
Brain	0.0094	0.0247	0.283	0.0206	0.0503	0.0013
Fat	0.0634	0.0497	--	0.219	0.0555	--

Table 5. Percent of tissue samples of woodcock, mourning doves, and robins from east-central Illinois with detectable levels of heptachlor, heptachlor epoxide, aldrin, dieldrin, p,p'-DDE and PCB's, August 1978 and 1979.

	Heptachlor	Heptachlor Epoxide	Aldrin	Dieldrin	p,p'-DDE	PCB's
Woodcock	0	39	0	85	15	8
Mourning Doves	0	55	0	83	24	3
Robins	14	67	5	43	29	14

and lowest in woodcock (Tables 4 and 5). The reverse was generally true for dieldrin; levels were higher in woodcock than in doves and lowest in robins. There was no consistent pattern for either DDE or PCB's. Environmental levels of DDE, dieldrin, and heptachlor epoxide in Illinois were probably lower in 1978-1979 than in earlier years, as those compounds gradually degrade (BEYER and GISH 1980, CAREY 1979, KLAAS and BELISLE 1977, LICHTENSTEIN et al. 1971, PIMENTEL 1971).

The apparent differences in levels of heptachlor epoxide and dieldrin among species of birds are probably due to differences in food habits. Earthworms (Lumbricidae), a principal food of numerous avians, including woodcock and robins, are resistant to DDT and its residues (BOYKINS 1970). Such residues have been found five times as high in earthworms as in the associated soils (BEYER and GISH 1980) and an order of magnitude higher in robins than in earthworms (DIMOND et al. 1970). One might expect woodcock and robins to have relatively similar levels of pesticide residues because both feed extensively on earthworms. Why doves rank between woodcock and robins in heptachlor epoxide and dieldrin content in the data reported here cannot be explained by the authors, except to point out that robins forage extensively in open urban lawns and gardens, taking a variety of invertebrates, whereas woodcock feed almost exclusively on earthworms in dense mesic forests.

Migratory birds undoubtedly reflect the chemical status of both winter and summer ranges. WRIGHT (1965) concluded that woodcock breeding in New Brunswick received high dosages of DDT on their breeding range where the insecticide had been applied to control spruce budworm (Choristoneura fumiferana) and heptachlor on their winter range where the latter insecticide had been used to control fire ants (Solenopsis saevissima). STICKEL et al. (1965) found that woodcock lose residues of heptachlor at a rate of 2.8% per day. MCLANE et al. (1978) found generally higher levels of pesticides in wings of adult woodcock east of the Appalachian Mountains, with particularly high levels in woodcock wings from New Jersey, the Carolinas, Georgia, and Louisiana; heptachlor epoxide was found only in wings of Louisiana woodcock.

Woodcock occur in Illinois from late February or early March through mid-November (William R. Edwards, unpublished data), but where these woodcock winter has not been determined with certainty. However, the incidence of heptachlor epoxide in Illinois and Louisiana woodcock and its absence in other collections reported by MCLANE et al. (1978) supports the concept of OWEN (1977) that woodcock breeding west of the Appalachians winter west of the Appalachians. The lack of heptachlor epoxide in wings of woodcock taken north of Illinois in Michigan, Wisconsin, and Minnesota (MCLANE et al. 1978) suggest that those populations are discrete from east-central Illinois woodcock.

MCLANE et al. (1971) reported mean values of 1.26 ppm (0.18-2.49) DDE, 0.149 ppm (0.022-0.62) heptachlor epoxide, and 0.090 ppm (0.023-1.09) dieldrin for woodcock wings; those values are generally higher than we report here for Illinois woodcock. The differences could relate to differences in environmental loads of pesticides in time, space, or tissues analyzed; however, MCLANE et al. (1971) concluded that Louisiana woodcock contained less heptachlor epoxide in 1965 than in 1961-1962. CLARK and MCLANE (1978) concluded that Louisiana woodcock in 1970-1971 had less DDE and less heptachlor epoxide than in 1965.

Although the number of samples assayed was small and their distribution restricted, it appears that residues of the organochlorine insecticides in woodcock, mourning doves, and robins probably remained widespread but at relatively low and probably decreasing levels in east-central Illinois in 1978-1979.

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EXPLORATORY EXPERIMENTS ON THE STABILITY OF MINERAL PROFILES OF FEATHERS

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Abstract: Feather chemistry has been suggested as a possible basis for identifying members of local populations of migratory birds. However, problems relating to the stability of feather-mineral profiles have not been resolved. Reported here are findings from an exploratory study of the stability of feather-mineral profiles. Mineral profiles of feathers were significantly affected by techniques of washing and of chemical analysis. Findings indicate that metal ions obtained from the environment are adsorbed to primaries. On exposure chemically different environments, mineral profiles of feathers become modified through ion exchange. Modification very possibly occurs throughout the life of a feather. Both ionic and covalent bonding are apparently involved. Although modified, profiles tended to maintain individuality and general group affinity thus potential use of mineral profiles in population analysis is not rejected. Methods for preparing sample feathers for analysis are discussed.

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This paper explores the stability of the mineral profiles of feathers and its significance to population analysis involving migratory birds. In the management of migratory birds it is desirable to differentiate members of local breeding populations and the origins of migrants seasonally using local areas. Several studies, including McCullough (1953), Schroeder et al. (1955), Devine and Peterle (1968), and Hanson and Jones (1968,1976), Schumann (1971), Neth (1971), Kelsall and Burton (1977), and Ranta et al. (1978) suggested that feather-mineral profiles offer potential for defining breeding and migratory populations.

The concept of mineral-profile analysis has been that the levels at which different elements are associated with feathers are functions influenced by the availability of those elements in the natal environment. Kelsall and Burton (1979) reported changes in feather chemistry between October and May for a captive population of snow geese. Means (1981) found high variances in profiles of feathers of Kirtland's Warbler (_Dendroica kirtlandii_). Data of Hanson and Jones (1976, Tables 2 & 5) suggested that profiles of feathers exposed to an "artificial" seawater may have become altered with respect to Na and Mg. An extensive literature on the mineral profiles of hair, which like feathers represent keratinized epidermal tissue, indicates that hair loses and gains metals from solution and that most ambient extractable minerals are not structurally significant (Schwartz 1960, Strain and Pories 1966, Bate 1966, Harmans 1967, Hinners et al. 1974, Flynn and Franzman 1974, Maugh 1978). Similarly, problems have been recognized relative to different analytical results relating to procedures for washing hair (Assarian 1977, Shopcott 1978, Chittleborough 1980, Salmela 1981).

Although Kelsall and Calaprice (1972:1096) sustained the earlier conclusion of Hanson and Jones (1968) that feather mineral profiles might serve as a means of tracing geographic origins of migratory birds, they concluded that variability existed that should be accounted for. Kelsall et al. (1975a,b) reported differences in feather mineral profiles among individuals of a common population and found rather consistent differences among primaries grouped by number (1,2...10); they also concluded that bilateral asymmetry was not a problem. Bush (1978) pointed out that amino acid composition differed markedly among feather parts in relation to structural differences of those parts. He also concluded that structural differences existed that were genetically regulated. Thus, the published findings on the mineral analysis of hair and feathers raised questions as to the stability of feather mineral profiles and hence the utility of using mineral profiles to trace geographic origins of migratory birds. Subsequent to the work presented here, Rose and Parker (1981) presented a model of feather mineral content as a function of time and rate of exposure as a function of distance from a source of metal pollution.

Research on the stability of feather mineral profiles reported here had 4 parts: (1) washing experiments to determine stability in response to different methods of washing and wash solutions, (2) the response of feathers to solutions high in salts of selected metals, (3) determinations of ion exchange properties of feathers, and (4) translocation experiments evaluating possible changes in mineral profiles of feathers of birds moved to new and chemically different environments.

Feathers of Canada geese (Branta canadensis) were used because (1) goose feathers are sufficiently large to analyze individually (2) sample goose wings were readily available through the courtesy of H. C. Hanson; and (3) much of the previously published work on feather minerals has been with wild geese.

H. C. Hanson, Illinois Natural History Survey (INHS), consulted extensively, provided the paired wings of geese which constituted the sample feathers, and reviewed drafts of the manuscript. R. L. Jones, Department of Agronomy, University of Illinois (UI), consulted on the chemistry of feather minerals, on analytical and statistical procedures, and was of significant help as a reviewer of drafts of this manuscript. T. J. Peterle and Susanne Wood also served as reviewers.

Other persons who facilitated this study include Scott Craven, U.S. Fish and Wildlife Service (USF&WS), Madison, Wisconsin; J. R. Karr, University of Illinois, Champaign; Robert Williamson, Illinois Department of Conservation (IDOC); personnel of the IDOC at the Moraine View State Park (Dawson Lake); and J. W. Seets, R. Siemers, and E. Brewer. Numerous other persons contributed in a variety of ways, particularly G. C. Sanderson and E. A. Anderson. The study was facilitated by contract funds provided by the U. S. Fish and Wildlife Service under the Accelerated Research Program (ARP) of that agency. Additional support was provided by the INHS, Section of Wildlife Research.

METHODS

Sample Feathers

Feathers for the washing and ion exchange experiments were from 8 pairs of wings of *B. c. interior* collected near Cairo, Illinois. Primaries were identified by sample number, whether left or right, and primary number; cut into 2- to 3-cm lengths (shaft portions below the vane were discarded, as were all broken, incomplete primaries); and individually sealed in glassine envelopes. Treated feathers were compared to feathers washed in DI-H_2O following the wash procedure of Hanson and Jones (1976); such feathers are referred to as untreated. Wild geese were captured and moved (translocated) to new environments. Untreated (right) primaries were taken at the time of capture with "treated" (left) primaries taken after exposure to the new environments.

Wash Solutions

The possible effects of wash solutions on mineral profiles was investigated by comparing data from sample feathers with data from comparable feathers washed in a surfactant solution and other washed in a weak acid solution. We hypothesized that if the minerals existed as relatively exchangeable ions adsorbed to the protein matrix of the feathers, washing surfactant or weak acid solutions might strip away the exchangeable ions and provide a picture of endogenous mineral profiles representative of natal areas and breeding ranges. Our purpose was to remove ions which could distort profiles and complicate analysis. Thus, we opted to test 0.05 N HCl as a wash solution. The decison to use an acid wash was arbitrary but one which would elucidate the principal of the removal of adsorbed ions.

Chemical Analysis of Feathers

For a comparison of agitation techniques, an ultrasonic cleaning bath was used to hold 8, 150-ml beakers, each containing a single feather in 100 ml of deionized water (DI-H_2O). For comparison, a reciprocating shaker operating at approximately 100 cycles/min was also used. For shaker-washing, single feathers were placed in 12 125-ml Erlenmeyer flasks in 100 ml of DI-H_2O. Wash waters were changed every 30 min in the agitation experiments and were analyzed for specific conductance. After washing, feathers were dried for 24 hr at 60°C, weighed into a Vycor crucible and ashed for 16 hr at 450°C. The ash was solubilized in concentrated nitric acid, transferred to a volumetric flask, and diluted to volume with ultrapure water. Chemical analysis was performed on a Jarrell-Ash Model 950 direct reading emission spectrometer equipped with an inductively coupled argon plasma source unit. Standards were prepared from high purity (99.999% or higher) metals or metal salts dissolved in ultrapure water in the presence of Ultrex grade acids.

Ion exchange capacity of goose feathers was determined by equilibrating 9th and 10th primaries from 4 pairs of goose wings with a 1N solution of $Ca(NO_3)_2$ in which the Ca^{2+} replaced the other adsorbed metals. This solution was then analyzed for calcium by emission spectrophotometry. Seventh and 8th primaries from these birds were equilibrated with 1N ammonium acetate by shaking for 2 hours to estimate the proportions of total metal ions in the feathers available for exchange. The solution was subsequently analyzed for sodium, potassium, calcium, and magnesium. The feathers were digested and analyzed as previously described. The general method was a modification of that described by Chapman (1965).

Statistical Analyses

Kelsall et al. (1975a,b) observed differences in feather chemistry related to primary number. This observation placed a constraint on the way feathers were grouped for experimentation. In our series of experiments, primaries were analyzed individually, with right primaries serving as controls for the respective treated left primaries with the innermost primary being "No. 1," and all others numbered in succession outward to No. 10, the last.

Subprogram DISCRIMINANT from the STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES (SPSS) was used to evaluate differences between treated and untreated groups and to identify chemical elements significant in group differences. Analyses were performed at the computer facilities of the University of Illinois, Urbana-Champaign.

FINDINGS

Agitation Experiments

The first experiment on the stability of feather mineral profiles concerned physical aspects of washing primaries in distilled water (DI-H_2O), i.e., the effects of (1) wash time and (2) the method of agitation of feathers washed in DI-H_2O. Because conductivity is a linear function of the log of the number of ions in solution, the conductivities of sequences of wash waters provided a basis for evaluating wash time and agitation as factors in profile stability. In the washing experiments the 1st and 2nd primaries, from 4 pairs of goose wings were used, thus potentially allowing 8 replicates for each test. Feathers were washed in 125-ml flasks with 100 ml of DI-H_2O, with wash waters changed every 30 min. Conductivities of blanks of distilled water averaged about 20 um after 30 minutes' agitation. Right 1st and 2nd primaries were washed using a reciprocating shaker for agitation, whereas left Nos. 1 and 2 were washed in the ultrasonic bath.

After 5 to 6 hr of washing (10 to 12 washes) the discarded wash waters had conductivities ≤ 50 umhos, and washing was discontinued. Possible differences in the rates at which ions were brought into solution between the 2 sources of agitation were tested using regression analysis of wash water conductivity (Y) and time (X). The hypothesis tested was that the coefficient of regression of conductivity over time was not significantly different between treatments. Data were corrected for differences in sizes of samples and were coded to log form to achieve approximate linearity of the X:Y relationships for purposes of regression analysis.

Regression coefficients for the decline in wash water conductivity in relation to wash time over 6.5 hr of washing for the coded data were b_a = 0.761 for feathers agitated in the reciprocating shaker and b_b = 0.805 for feathers washed in the ultrasonic bath. The difference between these regression coefficients was not significant (t_{11}) = 0.159). The conclusion drawn at this point was that approximately 25 washes (12.5 hr of wash time) would be required to "completely" wash a feather. From a practical standpoint, 5 to 6 hr of wash time appeared adequate. Summations of the conductivities of wash waters (not shown) indicated removal of virtually identical numbers of ions under the 2 methods of agitation. Although the sources of agitation were different, the sum of the conductivities agreed with an assumption of bilateral symmetry.

Primaries from the washing experiment were chemically analyzed to determine the concentration of 12 elements in the individual feathers (Table 1). Al and Fe values were found to be significantly greater in the primaries washed in the ultrasonic bath than in those washed in the shaker. One possible explanation is contamination of the former by Al and Fe from the glass beakers induced by prolonged agitation in the ultrasonic bath. Sums of ions from feathers washed in the bath, 1,330 ppm, and in the shaker, 1,271 ppm, suggested that similar levels of ion extraction had been achieved except for the probable contamination by Al and Fe. The agitation of large numbers of samples was much simpler using the shaker than using the ultrasonic bath. Because of practical considerations and the probable contamination by Al and Fe, a reciprocating shaker was used for washing feathers in subsequent phases of this study.

Wash Media Experiments

Surfactant Effects.--Right 5th and 6th primaries were wasehd in DI-H_2O for 6 hr, with the wash water changed hourly. Left 5th and 6th primaries were washed similarly using a 1% solution of "Triton X-100" (Rohm & Haas) in DI-H_2O as a surfactant. The sums of the 12 elements assayed were 944 ppm and 790 ppm, respectively, a difference of about 16 percent (Table 1); reduced levels were noted for 9 of 12 elements although only Ca and Mg levels were reduced significantly. However, the test of group differences was significant (P = 0.02). Posterior classification of all 14 sample feathers to their respective control groups was 100% correct. The response of treated feathers washed with the surfactant Triton X-100 was generally similar to that reported by Salmela et al. (1981) for human hair.

Effects of Washing in Dilute Acid.--Individual right (untreated) 3rd and 4th primaries were washed as before with left (treated) 3rd and 4th primaries handled similarly except that the wash solution was 0.05 N HCl; only 5 pairs of primaries were available for this evaluation.

The untreated primaries had an average of 954 ppm for the elements assayed, whereas primaries washed in the 0.05 N HCl solution averaged of only 693 ppm of the 12 elements--a reduction of almost 30% in total mineral load for the treated feathers (Table 1). Levels of K, Ca, Mg, Mn, and Zn were significantly reduced in the treated feathers, and group differences were significant at the 0.10 level ($\underline{P}$ = 0.0912). Posterior classifications of the 10 sample feathers, using discriminant analysis, was 100%. It is clear that washing in 0.05 N HCl removed significantly more ions from sample feathers than were removed by washing in DI-H_2O. Although no direct comparison was attempted between washing in 0.05 N HCl and use of a surfactant solution, results suggested that more ions were removed by the weak acid. The acid solution used had a pH of 1.56. Although relatively weak, that level of acidity would rarely be encountered in nature, but if encountered, it could be expected to strip away significant numbers of ions.

Salt-Loading Experiments

To test experimentally the possibility of environmentally induced ion exchange on feathers, sample feathers were exposed to a solution of metal salts, including the salt of a heavy metal, Zn. The left 7th, 8th, 9th, and 10th primaries from 4 pairs of sample wings were treated experimentally by shaking them individually for 48 hr in 250-ml flasks with 100 ml of a 1% solution of each of the chloride salts of Na, K, Ca, Mg, and Zn in DI-H_2O. The respective untreated right 7th, 8th, 9th, and 10th primaries were here again washed in DI-H_2O. After 6 hr total wash time, conductivities of the wash waters of the right primaries were in the range of 90-145 umhos, and the washing of the untreated primaries was discontinued. After exposure to the salt solution, the treated primaries were washed in 125-ml flasks with 100 ml

DI-H_2O for 6 hr, with the wash water changed hourly and checked for conductivity. After 6 hr of washing, conductivities of the wash waters from the treated (loaded) primaries were in the range of 860-1,600 umhos, and washing of the primaries was continued. Loaded left 7th and 8th primaries were washed for a total of 20 hr, with the final wash waters having conductivities in the range of 150-285 umhos. Loaded left primaries 9 and 10 were washed for 14 hr, with final wash waters having conductivities in the range of 200-355 umhos.

Results of the chemical analyses of the salt-loaded and respective untreated primaries were dramatically different (Table 1). Although the solution used contained the salts of Na, K, Ca, and Mg, those elements were much reduced on the treated primaries. In fact, all assayed elements except Zn, B, Si, and P were significantly reduced; however, Zn was increased by a factor of about 7. Ion loads for the treated feathers averaged 1,233 ppm; this was 18% greater than the average of the untreated feathers, 1,043 ppm. However, for the 11 elements other than Zn, the untreated feathers averaged 940 ppm, whereas the treated feathers averaged only 500 ppm. This difference suggests that Zn in the salt solution displaced approximately 47% of ions of those 11 elements on the treated feathers. Differences were highly significant ($p < 0.002$, Table 2). The stripping effect of the heavy metal zinc was even more effective than washing with 0.05 N HC1 in removing ions adsorbed to primaries. All 26 treated feathers were correctly assigned, using discriminant analysis. Even after Zn had stripped away nearly half of the adsorbed ions, residual feather-mineral profiles remained that appeared potentially indicative of the individuals' natal environments.

The observed responses of feathers to zinc in the washing and loading experiment were consistent with ion exchange. Griffin et al. (1976) found that the retention of Zn in soil was accompanied by the release of Ca and Mg. Gibb et al. (1977) concluded that the principal mechanism of the uptake and retention of Zn by soils from groundwater was by cation exchange, with ions exchanged in reverse order of their mobilities. Luckey and Venugopal (1977) point out that metal ions interact with amino acids and proteins. The latter workers state (1977:120) that metals with empty orbitals, Ca and Mg for example, and those with half-filled orbitals, such as Mn^{2+} and Fe^{3+}, form coordination compounds (ionic bonds), whereas metals, such as Co^{2+}, Co^{3+}, Ni^{2+}, Cu^{2+}, and Zn^{2+}, form the stronger covalent bonds. Crist et al. (1981) also conclude that both ionic and covalent bonding are involved in adsorbtion of metals to proteins of algal cell surfaces.

In discussing metal-protein bonding, Luckey and Venugopal (1977:120) indicate that the stability of ionic bonds is governed by electrostatic attractions directly related to ionic charge and inversely related to ionic radius, whereas the stability of covalent bonds is not so related (1977:121). Crist et al. (1981:1217) conclude that displacement of metal ions proceeds in the general order of Cu > Sr > Zn > Mg > Na. Thus, on the basis of chemical properties, one would expect mineral profiles of feathers to change on exposure to new and chemically different environments, with change dependent on (1) the prior chemical state of the feather and (2) the chemical state of the new environment. In particular, one could expect feathers of migratory birds in the wild to show an increase over time in the general abundance of metals having relatively high bond strengths.

Translocation Experiments

Research on mineral profiles of hair (Schwartz 1960, Bate 1966, Hinners et al. 1974) suggested that the mineral profiles of primaries may become modified on exposure to new and chemically different environments. The stability of mineral profiles of free living geese exposed to new environments was investigated by comparing the profiles of right (untreated) primaries of wild geese sampled immediately on capture to those of left (treated) primaries of the same geese sampled several months after those geese had been transferred and exposed to new environments.

Two geese (No.s 1 and 2) captured by cannon netting at the Horicon National Wildlife Refuge, Horicon, Wisconsin, in October 1977 were released on the day of capture on the Vivarium Pond at the University of Illinois, Urbana. These birds were believed migrants from the James Bay area of Canada and members of the so called "Mississippi Valley Population" (MVP). Two geese (Nos. 3 and 4) identified as B. c. maxima were captured in October 1977 from a local flock at Dawson Lake, McLean County, Illinois, and were transferred to the Vivarium Pond as above. Two more B. c. maxima (No.s 5 and 6), also taken at Dawson Lake in October 1977, were similarly released at the Little John Conservation Area, Knox County, Illinois. The treated (left) primaries for the 2 B. c. maxima at Little John were taken in mid-January 1978. The treated primaries of the 4 geese held at the Vivarium Pond were taken in June 1978.

At Little John the geese had access to a series of ponds developed during surface mining for coal done about 30 years earlier; soil profiles were destroyed during mining. The present soils are derived from overburden, which is a mixture of 6 ± 1.5 m of weathered calcareous glacial till, 6 ± 1.5 m of light to medium gray shale, 30 cm of dense limestone, 15 cm of dark (acid) clay stone, and 30 cm of dark (acid) shale. In general, the soils and waters at Little John have relatively high pH. Dawson Lake was man made and is situated on the Bloomington moraine, which formed during the final stage of the Wisconsinan glaciation. Soils in this area formed under prairie in 60-120 cm of loess over calcarious till; soil and water pH tend to be relatively high. The Vivarium Pond is fed by a continuous flow of city water obtained from deep wells in glacial drift.

Horicon to Vivarium Pond.--Two geese, Nos. 1 and 2, were involved. Levels of Ca, Mg, and Zn were significantly increased in the treated primaries of geese translocated from Horicon to the Vivarium Pond (Table 2). Total ion loads averaged 1,107 and 1,353 ppm, respectively, for the untreated and treated primaries of goose No. 1, an increase of 22%, and 920 and 1,099 ppm, respectively, for goose No. 2, an increase of 19%. However, both geese showed reductions in Na and Mn in the treated primaries; Mn was significantly lower in goose No. 2. In both instances the mineral profiles of treated and untreated groups differed significantly, and in both instances all primaries were correctly assigned to their respective groups, using discriminant analysis. The difference between treated and untreated primaries is strong evidence that mineral profiles of the Horicon geese became altered following translocation to the Vivarium Pond.

Dawson Lake to Vivarium Pond.--Two geese, Nos. 3 and 4, were involved. Levels of Ca and Mg were significantly increased, and levels of Al, Fe, and P were significantly reduced in the treated primaries as compared with the untreated right primaries of Dawson Lake geese transferred to the Vivarium

Pond (Table 2). Total ion loads averaged 1,074 and 1,077 ppm, respectively, for the untreated and treated primaries for goose No. 3, and 1,186 and 1,266 ppm, respectively, for #458, an increase of 7% for goose No. 4. Although total ion loads were not greatly increased, group differences were significant at the P = 0.05 level for goose No. 3 and at the P = 0.01 level for goose No. 4; all primaries from both #457 and #458 were correctly assigned to their respective groups, using discriminant analysis. Changes in ion loadings of the Horicon and Dawson geese translocated to the Vivarium Pond either tended to be in the same direction or toward more common levels as suggested, for example, by reduction in the high levels of Al and Fe from treated feathers of the Dawson Lake geese.

Dawson Lake to Little John.--Two geese, No.s 5 and 6, were involved. Compared with those of the 4 geese translocated to the Vivarium Pond, primaries of the 2 geese moved to Little John showed less change although trends were similar in several respects (Table 2). For example, Ca and Mg increased, with Mg significant at the P = 0.05 level and Ca at the P = 0.10 level, for goose No. 5. Average ion loads were 1,172 and 1,243 ppm, respectively, for untreated and treated feathers for goose No. 5, an increase of 6%, and 1,216 and 1,335 ppm, respectively, for goose No. 6, an increase of 10%. Differences in mineral profiles between untreated and treated primaries were significant at the P = 0.05 level for No. 5 and at the P = 0.01 level for No. 6. All 38 primaries were correctly assigned to groups by posterior classification.

As suggested by the results of washing, loading, and ion exchange experiments, feather mineral profiles were in fact dynamic and responsive to new and chemically different environments. Analyses for the translocated geese demonstrated that individuality was maintained after translocation--that is, mineral profiles of individual translocated birds were significantly different from those of other translocated birds (Fig. 1). The general tendency to increased ion loads over time is consistent with Rose and Parker (1981). Posterior classifications of all feathers from translocated geese, using discriminant analysis to groups, was 100% correct. These findings suggest that even though mineral profiles became modified as a consequence of the gain and loss of exchangeable ions in response to new and chemically different environments, individuals sustained their identities. This suggests that had sample sizes been adequate, groups would likely have maintained their individuality.

Primary Number Effect

To test for possible feather-number effect, the untreated right primaries from the washing and loading experiments were arranged in 10 groups by primary number; data were available for 33 right primaries representing 4 geese; the washing of the untreated primaries has been discussed. The elements Na, K, Ca, B, Fe, P, and Zn were found to differ significantly among the untreated primaries from the washing and loading experiments when grouped by primary number. In general, as feather number increased, Na and K tended to increase, whereas levels of Ca, B, Fe, P, and Zn tended to decrease. Posterior classification of the 33 feathers to their respective groups was 100% correct. In general, primaries No. 1, 2, 8, 9, and 10 showed significant differences from other groups, whereas Nos. 3, 4, 5, 6, and 7 were not significantly different.

Control primaries from 4 geese used in the translocation experiments from Dawson Lake also showed significant differences among groups for Na, B, and Si; K exceeded the reference value at the P = 0.10 level. Posterior classifications correctly identified 31 of the 38 (82%) primaries (Table 3). In general, the most desirable grouping in this series was that of primaries Nos. 6, 7, and 8.

The analysis of feather-number effect was flawed by our not having equal sample sizes among groups representing the same individuals. However, both data sets showed generally similar patterns that substantially agreed with the findings of Kelsall et al. (1975a,b). The inference drawn was that in developing mineral profiles, feathers should not be selected indiscriminately. It appears advantageous to pool primaries Nos. 5, 6, and (or possibly 4, 5, 6, and 7) as a general practice.

Cation Exchange Capacity of Feathers

Because previous results suggest the adsorption of ions to feathers, primaries No. 9 and 10 from 4 additional pairs of wings, 16 total feathers, were used to estimate cation exchange capacity (CEC) using a procedure based on Chapman (1965). The mean CEC for the feathers examined was 0.124 milliequivalents of Ca/g of feather, confirming the previously suspected adsorption of ions to feathers (Table 4).

Extraction of cations from primaries by 1 N ammonium acetate resulted in the removal of 86, 88, 68, and 56%, on the average, of the Na, K, Ca, and Mg, respectively (Table 4). Findings demonstrated that a high proportion of the ions associated with feathers were exchangeable, although, the 1 N ammonium acetate undoubtedly extracted more ions than might normally be exchanged under natural conditions. Results of the ion exchange experiments are in accord with Schwartz's (1960) conclusion that metals bind to cystine of hair although several amino acids in addition to cystine may be involved (Schroeder et al. 1955, Bush 1978).

DISCUSSION

Our findings are consistent in principle with related findings of research on the washing of human hair prior to trace mineral analysis (Assarian 1977, Maugh 1978, Shapcott 1978, Salmela et al. 1981) and with findings on chemical binding and exchange of metal ions on proteins (Luckey and Venugopal 1977, Crist et al. 1981). Rose and Parker (1981) made the important distinction that feather mineral profiles reflect exogenous adsorption. Our findings support that conclusion.

The fact that feather-mineral profiles have been found to be dynamic on exposure to new and chemically different environments compromises to some unknown degree the potential utility of feather-mineral profiles in population studies. Eventually, the utility of feather mineral profiles must be demonstrated by functional use in field studies. In any event, results of our findings, like those of Salmela et al. (1981), clearly demonstrate that techniques of sample preparation must be standardized if the data are to be compared among studies or areas and over time. Yet to be answered are questions as to how sample preparation would allow the highest probability of correct classification of individuals to groups.

In effect, one question is how clean is clean enough? That question must for now remain unanswered, but some consideration of standardized procedures is in order. Wash water obviously should have a high level of purity (conductivity ≤25 um), and glassware should be washed in Alconox (Curtin Mathesin Scientific Co.) or comparable glass cleaner, rinsed in high-purity water, and again rinsed in 30 percent NHO_3. The removal of surficial "dirt" is logical. The use of a reagent-grade organic solvent, such as hexane, as a prerinse (Salmela et al. 1981) to remove grease, and the addition of a non-ionic detergent such as Triton X-100 (1% solution), to facilitate cleaning appear desirable.

Schroeder et al. (1955) found different concentrations of amino acids with different metal binding capacities in various parts of feathers. Our findings and those of Kelsall, et al. (1975a,b) demonstrate variability in mineral profiles related to feather number. We believe standardization of feather parts and feather numbers to be important. Because it will sometimes be desirable to sample feathers from living birds, it seems desirable routinely to trim the bases of all feathers just below the vanes. It further seems desirable to discard incomplete feathers. To minimize feather-number effect, we propose working only with primaries 5, 6, and 7, and that those feathers be pooled for the individual bird. We see no problem in pooling or substituting right or left primaries of the same number from normal birds.

A major unresolved point is whether readily exchangeable ions should be removed prior to assay, and if so, how this should be accomplished. It might be argued that the removal of exchangeable ions, leaving a "base" profile of tightly bound ions, could give a profile most characteristic of the environment where the feather was produced--of the breeding or summer range. This may be the case. However, because ions are exchanged on the basis of bond strength, adsorbtion of strongly held ions could conceivably occur throughout the life of the feather, and stripping feathers of lightly bound ions would not necessarily give a profile most indicative of the breeding or summer range of the individual. On the contrary, the stripping of lightly bound ions could result in the loss of important information relating to such ions.

. Although we have evidence that profiles are dynamic, it does not necessarily follow that the feather mineral analysis will make no contribution to population analysis and management. We believe that on the basis of promise reported on field studies, feather mineral analysis warrants additional experimental study and use.

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Table 1. Summary of group means for untreated and treated primaries for chemical analyses from washing and salt-loading experiments.[a,b,c]

	Shaker vs. ultrasonic bath 1 & 2[d] (7)[e]		$DI-H_2O$ vs. surfactant solution 5 & 6 (7)		$DI-H_2O$ vs. 0.05 N HCl 3 & 4 (5)		$DI-H_2O$ vs. salt loaded 7,8,9,&10 (13)	
	Shaker	Bath	$DI-H_2O$	Surfactant	$DI-H_2O$	0.05N HCl	$DI-H_2O$	Salt Loaded
Na	70.3	74.1	55.5	36.4	60.8	56.0	130	16.1
K	32.2	24.6	18.9	14.3	17.3	34.7*	42.1	17.5*
Ca	464	436	384	327*	351	151***	378	187***
Mg	129	138	112	67***	101	59**	116	91***
Al	46.5	82.9*	35.7	26.6	37.5	65.0	37.2	25.4*
B	2.20	2.06	1.84	1.65	2.60	1.99	1.54	1.61
Cu	5.03	4.68	4.71	4.91	4.99	3.85	5.19	2.19***
Fe	98	136*	50.5	51.0	56.3	73.0	49.5	30.4***
Mn	3.54	3.99	2.05	1.94	1.84	1.17*	2.30	0.77***
P	210	210	131	119	149	139	132	167
Si	90.4	98.0	46.4	30.4	65.1	57.1	45.2	42.9
Zn	120	120	101	110	107	51***	104	733***
Sum	1,271	1,330 (+5%)	944	790 (-16%)	954	693 (-27%)	1,043	1,233 (+18%)
Difference Probability		0.0071**		0.0153*		0.0912*		<0.0000***

[a]Given in ppm of feathers; all feathers used are from the same 4 geese (Nos. 3501, 3502, 3503, 3504).

[b]Significant at P = *0.05, **0.01, and ***0.001.

[c]Solution contained 1% each of the chloride salts of Na, K, Ca, Mg, and Zn.

[d]The numbers of the primaries used in each experiment.

[e][illegible]

Table 2. Summary of group means for untreated and treated primaries for chemical analyses of feathers of geese in translocation experiments.[a,b]

	Horicon to Vivarium Pond				Dawson Lake to Vivarium Pond				Dawson Lake to Little John			
	No. 1 (8)[c]		No. 2 (8)		No. 3 (8)		No. 4 (10)		No. 5 (10)		No. 6 (10)	
	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
Na	65.9	40.1	41.4	26.8	48.9	55.2	31.1	35.5	78.2	58.1	33.9	25.0
K	31.1	32.5	19.1	17.3	32.6	23.7	21.3	15.9	28.5	31.3	21.7	21.2
Ca	569	759***	461	609***	411	516***	568	713***	543	595^{+}	655	673
Mg	107	138***	97	126***	99	119***	127	156***	137	158**	118	140
Al	19.0	22.0	17.3	18.2	82.7	38.5***	69.0	27.0***	30.0	34.6	47.8	69.5^{+}
B	42.7	44.5	20.2	22.1	13.6	16.3	12.3	12.7	81.9	78.8	68.5	61.1
Cu	3.67	4.54^{+}	3.59	4.09	4.95	5.24	6.53	8.00^{+}	7.56	7.84	6.04	6.31
Fe	56.9	67.6	50.0	48.1	96.2	58.5**	92.0	58.7**	46.5	54.9	59.7	114.0
Mn	2.56	1.96	3.07	1.87**	8.12	5.70	11.75	7.80^{+}	3.36	3.33	5.07	6.21
P	56.3	50.9	44.5	42.6	42.1	39.2*	51.5	48.6*	46.3	45.5	39.0	41.0
Si	43.5	52.6	54.5	46.0	71.1	72.1	76.5	61.2	48.6	52.1	61.9	64.2
Zn	104	139***	108	137**	119	128	119	122	121	124	99	113
Sum	1,107	1,353 (+22%)	920	1,099 (+19%)	1,074	1,077 (+0.003%)	1,186	1,266 (+7%)	1,172	1,243 (+6%)	1,216	1,335 (+10%)
Difference Probability			P = 0.0005***		P = 0.0254*		P = 0.0002***		P = 0.00472*		P = 0.0012	

[a] Given in ppm of feathers.

[b] Significant at P = $^{+}$0.10, *0.05, **0.01 and ***0.001.

[c] Bird number followed by sample size (number of pairs) in parentheses.

Table 3. Summary of results of tests of differences in feather mineral profiles of primaries grouped by number for untreated primaries (Table 6), from geese from Dawson Lake used in translocation; feathers washed in DI-H_2O.[a]

Primary Number (= Groups)	Primary Number (= Groups) 1	2	3	4	5	6	7	8	9
2	0.7615								
3	0.1216	0.3993							
4	0.0310	0.1736	0.1878						
5	0.0319	0.0870	0.1556	0.2666					
6	0.0017	0.0076	0.0466	0.2692	0.5920				
7	0.0006	0.0017	0.0111	0.0340	0.3838	0.9663			
8	0.0001	0.0004	0.0024	0.0088	0.1348	0.7461	0.8154		
9	0.0003	0.0005	0.0013	0.0081	0.1637	0.3582	0.4650	0.7720	
10	0.0002	0.0003	0.0024	0.0026	0.0644	0.1837	0.2666	0.7547	0.8125

[a]Given as probability of no significant difference between mineral profiles of 2 groups of feathers.

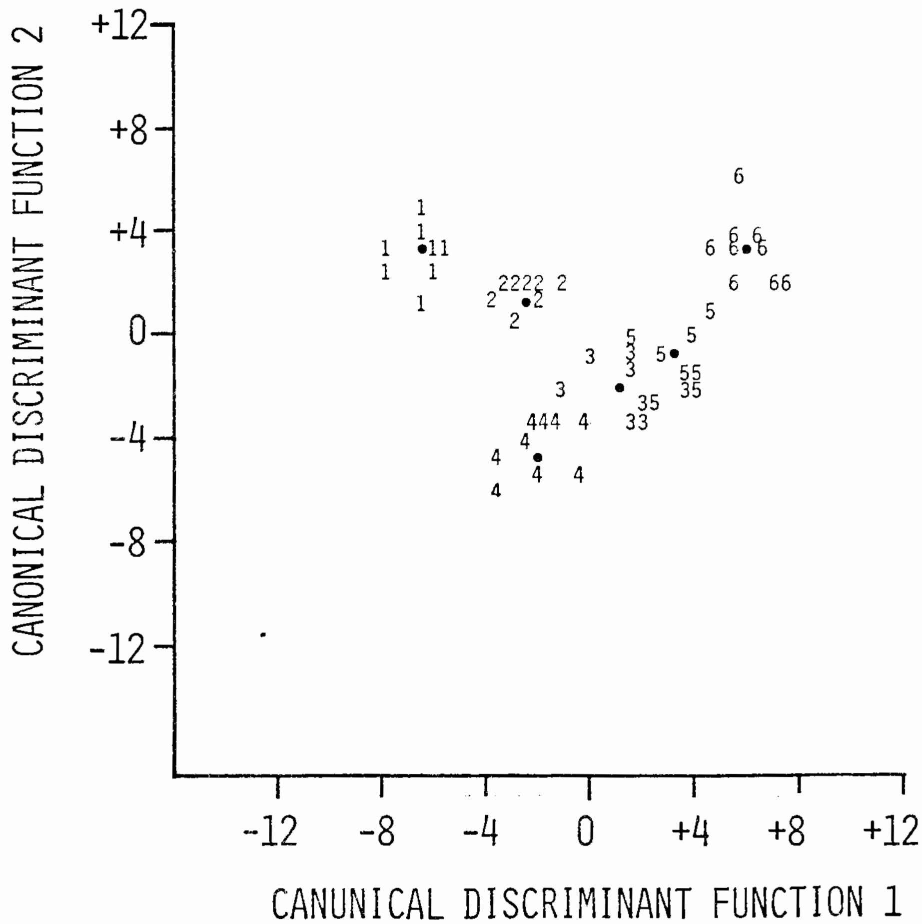
Table 4. Summary of cation ion exchange characteristics (CEC) of Canada goose primaries.

Element	(Na)	(K)	(Ca)	(Mg)	
% Removed*	86	88	68	56	
% Residual	14	12	32	44	
Bird No.**	(1)	(2)	(3)	(4)	($\bar{X}$)
CEC	0.115	0.102	0.119	0.159	0.124

*Removed by saturation with 1 N ammonium acetate; means of 7th and 8th primaries from 4 geese (n = 16).

**Milliequivalents per 100 g feather for pooled samples of 9th and 10th primaries.

Fig. 1. A plot of classification of treated primaries based on discriminant analysis using 12 elements for translocated geese: Nos. 1 and 2 from Horicon to the Vivarium; Nos. 3 and 4 from Dawson Lake to the Vivarium; Nos 5 and 6 from Dawson Lake to Little John. Group centroids are indicated by "*" (49 of 57 feathers plotted; 8 are "buried").


CANONICAL DISCRIMINANT FUNCTION 2
+12
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+4
0
-4
-8
-12
-12
-8
-4
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+12
CANUNICAL DISCRIMINANT FUNCTION 1

Table 1. Summary of woodcock recapture data.

Band Number	Sex	Capture Age	Capture Date	Capture Location	Recapture Age	Recapture Date	Recapture Location	Distance from: initial capture
1323-65419	F	U	06/04/79	Forest Glen (6.23/7/27)	U	08/08/79	Forest Glen (6.08/6.08)	0.6 km
1323-65451	M	SY	04/14/81	Forest Glen (12.37/4.30)	SY	05/19/81	Forest Glen (11.25/2.05)	1.2 km
1323-65452	M	ASY	04/16/81	Kennekuk Cove initial area	ASY	09/16/81	Kennekuk Cove	0
1323-65453	M	SY	04/17/81	Kennekuk Cove initial area	SY	07/30/81	Kennekuk Cove	0
						09/16/81	Kennekuk Cove	0
1423-16809	M	AHY	09/09/81	Forest Glen (5.09/6.27)	AHY	09/10/81	Forest Glen (5.30/6.07)	0.2 km
1323-65476	M	HY	06/22/81	Forest Glen Tower Field	SY	04/01/82	Forest Glen Tower Field (9.37/5.30)	0
1323-65451	M	SY	04/14/81	Forest Glen Pipeline Road-North Field (12.20/3.05)	AHY	04/13/82	Forest Glen Cemetary Field (11.20/2.07)	0.6 km
1423-16814	M	AHY	10/16/81	Kennekuk Cove Field #27	ASY	04/30/82	Kennekuk Cove Field #29	0.4 km
1423-16836	M	SY	04/23/82	Forest Glen Power Line Field (5.09/6.28)	SY	06/01/82	Forest Glen Gate Field South (6.12/5.30)	0.6 km

Master Permit No. 6507

Banding Schedule 3-860 Rev. 1973

Master Permittee Ill. Nat. Hist. Surv.

FROM 1423-16824
THROUGH 1423-16862
REPORT ONLY CONTIGUOUS BAND NUMBERS

—Banding Locations—

A Forest Glen Nature Preserve 4.4 mi ESE Westville, VermilionCo.IL

B Kennekuk Cove 4.7 mi NNE Oakwood, Vermilion Co.IL

C Spaulding Park, Champaign Champaign County, IL

D

E

F

BAND PREFIX 1423	COMMON NAME	AOU #	STATUS	AGE-SEX	REGION	LAT-LONG	LOC	DATE MO—DAY—YR
168 01								
02								
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168 24	American Woodcock	228.0	300	ASY - M	IL - 234	400 - 0873	A	03/23/82
25				ASY - M			A	04/01/82
26				ASY - M			A	"
27				ASY - F			A	"
28			315	ASY - F		400 - 0881	C	04/09/82
29			300	SY - M		400 - 0873	A	04/13/82
30				ASY - F			A	"
31				SY - M			A	04/16/82
32				SY - M			A	04/21/82
33				SY - M			A	"
34				ASY - M			A	04/22/81
35				ASY - M			A	"
36				SY - M			A	04/23/82
37			315	ASY - M			A	"
38			300	SY - M			A	"
39				SY - M			A	"
40				ASY - M		401 - 0874	B	04/29/82
41				SY - M			B	05/03/82
42				ASY - M			B	"
43				SY - M			B	"
44				ASY - M			B	05/04/82
45				SY - M			B	"
46				ASY - M			B	"
47				SY - M			B	"
48				ASY - M			B	"
49				ASY - M		400 - 0873	A	05/10/82
50				HY - M			A	05/17/82

Master Permit No. 6507

BAND PREFIX 1423 ←	COMMON NAME	AOU #	STATUS	AGE-SEX	REGION	LAT-LONG	LOC	DATE MO—DAY—YR
168 51	American Woodcock	228.0	300	HY F	IL 234	400 - 0873	A	05/21/82
52				ASY F			A	05/24/82
53				HY F			A	05/25/82
54				ASY M			A	"
55				HY F			A	05/28/82
56				SY M			A	06/01/82
57				HY M			A	"
58				HY M			A	"
59				HY M			A	06/02/82
60				HY F			A	06/03/82
61			315	HY F			A	"
62			300	HY M			A	06/09/82
63								
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REMARKS

1423-16823 Bird flushed into an overhang on a building during the morning hours followin a blizzard snowstorm. Appeared to have some loss of locomotor ability. This bird was released about 1/4 mile away in a small wooded park area within the city limits (Spaulding Park).

1423-16861 compound dislocation of the distal end of the first phalanx on the third (middle) toe. Bone was reset, a temporary splint was applied and the bird was released in diurnal cover.

1423-16837 - skin was torn in ventral area under wing exposing some pectoral limp muscle